What is claimed is:

Claims

1. An optical chip, comprising:

at least one large mode field size dielectric waveguide to interface with an external optical device;

at least one low minimum bending radius dielectric waveguide coupled to the large mode field size dielectric waveguide; and

at least one optical function connected to the low minimum bending radius dielectric waveguide;

wherein the large mode field size dielectric waveguide, the low minimum bending radius dielectric waveguide, and the optical function are fabricated monolithically on a single substrate.

2. The optical chip of claim 1, wherein the external optical device is a fiber optic waveguide.

3. The optical chip of claim 1, wherein the external optical device is selected from one or more of an edge emitting/receiving optical device and a vertically emitting/receiving optical device.

4. The optical chip of claim 1, wherein the external optical device is a large mode field size fiber optic waveguide on a separate chip.

5. The optical chip of claim 1, further comprising a coupler to couple the low minimum bending radius dielectric waveguide to the large mode field size dielectric waveguide, wherein the coupler includes:

a first dielectric channel waveguide including a first core material having a first tapered region surrounded by a cladding material; and

a second dielectric channel waveguide including a second core material having a second tapered region surrounded by the cladding material, a portion of said second tapered region being embedded within said first tapered region, wherein a first mode for propagating lightwaves defined by the first dielectric channel waveguide gradually transforms into a second mode defined by the second dielectric channel waveguide.

6. The optical chip of claim 5, wherein the embedded portion of said second tapered region of the coupler is completely surrounded by said first tapered region in a cross-section transverse to a mode transformation direction.

7. The optical chip of claim 5, wherein the first tapered region of the coupler gets narrower in width in direction toward the second dielectric channel waveguide, and wherein the second tapered region gets narrower in width in direction toward the first dielectric channel waveguide.

8. The optical chip of claim 7, wherein the first tapered region and the second tapered region are graded in the horizontal direction.

9. The optical chip of claim 8, wherein the first tapered region and the second tapered region are graded in the vertical direction.

10. The optical chip of claim 5, wherein the large mode field size dielectric waveguide is optically coupled to the first dielectric channel waveguide of the coupler.

11. The optical chip of claim 10, wherein the first mode defined by the first dielectric channel waveguide of the coupler is similar in size to a mode defined by the large mode field size dielectric waveguide.

12. The optical chip of claim 10, wherein the low minimum bending radius dielectric waveguide is optically coupled to the second dielectric channel waveguide of the coupler.

13. The optical chip of claim 12, wherein the second mode defined by the second dielectric channel waveguide of the coupler is similar in size to a mode defined by the low minimum bending radius dielectric waveguide.

14. The optical chip of claim 1, wherein the large mode field size dielectric waveguide is a low index difference dielectric waveguide, and wherein the low minimum bending radius dielectric waveguide is a high index difference dielectric waveguide

15. The optical chip of claim 14, wherein the low index difference dielectric waveguide includes a low index core and a cladding, wherein the index of refraction n_1 of the low index core and the index of refraction n_3 of the cladding are related as follows:

$$0<\frac{n_1-n_3}{n_3}<0.1.$$

16. The optical chip of claim 15, wherein the high index difference dielectric waveguide includes a high index core and the cladding, wherein the index of refraction n_2 of the high index core and the index of refraction n_3 of the cladding are related as follows:

$$0.1\leq\frac{n_2-n_3}{n_3}.$$

17. The optical chip of claim 15, wherein:

$$0 < \frac{n_1 - n_3}{n_3} < 0.04.$$

18. The optical chip of claim 16, wherein:

$$0 < \frac{n_1 - n_3}{n_3} < 0.01.$$

19. The optical chip of claim 18, wherein:

$$0.3 \leq \frac{n_2 - n_3}{n_3}.$$

20. The optical chip of claim 1, wherein the low minimum bending radius dielectric waveguide includes:

a high index core material defining a channel;

a first cladding region generally surrounding the high index core material, wherein a refractive index n_2 of the high index core material is greater than a refractive index n_3 of the first cladding region; and

a graded index region, wherein the graded index region is a separate region applied between at least one side of the high index core material and the first cladding region.

21. The optical chip of claim 20, wherein the graded index region has a refractive index that gradually changes from a refractive index of the high index core material to a refractive index of the first cladding region.

22. The optical chip of claim 20, wherein the at least one side having the graded index region is a rough edge of the high index core material.

23. The optical chip of claim 20, wherein the graded index region is applied between two rough sides of the high index core material and the first cladding region.

24. The optical chip of claim 20, wherein the graded index region is applied between each side of the high index core material and the first cladding region.

25. The optical chip of claim 20, wherein the first cladding region comprises two or more separate regions of cladding material.

26. The optical chip of claim 20, wherein the graded index region reduces scattering loss.

27. The optical chip of claim 1, wherein the optical function is any structure that performs at least one of generating, modifying, and measuring at least one of the amplitude, frequency, wavelength, dispersion, timing, propagation direction, and polarization properties of one or more light pulses.

28. An optical chip comprising a plurality of optical functions and at least one input/output port, wherein the optical functions and input/output port are fabricated on a substrate, the optical functions being optically connected with interconnection waveguides, wherein at least one of the interconnection waveguides between two or more of the optical functions is a low minimum bending radius waveguide, and wherein the optical chip includes at least 5 optical functions per square centimeter.

29. The optical chip of claim 28, wherein the optical chip includes at least 10 optical functions per square centimeter.

30. The optical chip of claim 28, wherein the low minimum bending radius waveguide includes a high index core material with an index of refraction n_2 and a cladding material with an index of refraction n_3, wherein $0.1 \leq \frac{n_2 - n_3}{n_3}$.

31. The optical chip of claim 30, wherein $0.3 \leq \frac{n_2 - n_3}{n_3}$, and wherein the low minimum bending radius waveguide has a bending radius of no more than 50 microns.

32. The optical chip of claim 30, wherein the input/output port includes a low index difference waveguide, wherein the low index difference waveguide includes a low index core material having an index of refraction n_1 surrounded by the cladding material, wherein $0 < \frac{n_1 - n_3}{n_3} < 0.04$.

33. A substrate comprising:

at least one optical function connected to at least one low minimum bending radius dielectric waveguide;

at least one large mode size dielectric waveguide to interface with an external optical device; and

a coupler to couple the low minimum bending radius dielectric waveguide with the large mode size dielectric waveguide, wherein the coupler optically connects the low minimum bending

radius dielectric waveguide with the large mode size dielectric waveguide with no more than 1 dB of loss.

34. The substrate of claim 33, wherein the high index difference dielectric waveguide includes a high index core material with an index of refraction n_2 and a cladding material with an index of refraction n_3, wherein $0.1 \leq \frac{n_2 - n_3}{n_3}$.

35. The substrate of claim 34, wherein the low index difference dielectric waveguide includes a low index core material having an index of refraction n_1 surrounded by the cladding material, wherein $0 < \frac{n_1 - n_3}{n_3} < 0.04$.

36. An apparatus, comprising:

a first optical chip including:

at least one large mode size dielectric waveguide;

at least one low minimum bending radius dielectric waveguide coupled to the large mode size dielectric waveguide; and

at least one optical function connected to the low minimum bending radius dielectric waveguide, wherein the optical function, large mode size dielectric waveguide, and low minimum bending radius dielectric waveguide are monolithically fabricated on a single substrate; and

a second optical chip including an emitting/receiving optical device to optically connect to the large mode size dielectric waveguide of the first optical chip.

37. The apparatus of claim 36, wherein a first end of the large mode size dielectric waveguide on the first optical chip includes an anti-reflection coating.

38. The apparatus of claim 36, wherein the emitting/receiving optical device on the second optical chip includes an anti-reflection coating.

39. A planar lightwave circuit substrate, comprising:

at least one optical function connected to at least one low minimum bending radius dielectric waveguide, wherein the low minimum bending radius dielectric waveguide includes a high index core material, a first cladding region generally surrounding the high index core material, and a graded index region applied between at least one side of the high index core material and the first cladding region;

at least one large mode size dielectric waveguide to interface with an external optical device; and

a coupler to couple the low minimum bending radius dielectric waveguide to the large mode size dielectric waveguide, wherein the coupler includes:

a first dielectric channel waveguide including a first core material having a first tapered region surrounded by a cladding material; and

a second dielectric channel waveguide including a second core material having a second tapered region surrounded by the cladding material, a portion of said second tapered region being embedded within said first tapered region, wherein a first mode defined by the first dielectric channel waveguide gradually transforms into a second mode defined by the second dielectric channel waveguide, and wherein the first dielectric channel waveguide is optically connected to the large mode size dielectric waveguide and the second dielectric channel waveguide is optically connected to the low minimum bending radius dielectric waveguide.

40. An apparatus, comprising:

an optical chip including

at least one large mode field size dielectric waveguide to interface with an external optical device;

at least one low minimum bending radius dielectric waveguide coupled to the large mode field size dielectric waveguide; and

at least one optical function connected to the low minimum bending radius dielectric waveguide, wherein the large mode field size dielectric waveguide, the low minimum bending radius dielectric waveguide, and the optical function are fabricated monolithically on a single substrate; and

at least one external large mode field size dielectric waveguide external to the optical chip and being optically connected to the optical chip.

41. The apparatus of claim 40, wherein a first end of the external large mode field size dielectric waveguide is optically connected to the large mode field size dielectric waveguide on the optical chip.

42. The apparatus of claim 41, wherein a second end of the external large mode field size dielectric waveguide is adapted to be connected to external optical devices.